Developing a Precision Rocket Landing Algorithm Using Convolutional Neural Networks and Model Predictive Control Algorithms

Erbas, Timucin (School: Acton Boxborough Regional High School)

In future interplanetary missions, rockets must land on smooth terrain to avoid damaging their boosters or tipping over. Currently, scientists can narrow down Mars mission landing spots within an ellipse measuring 7.7 x 6.6 kilometers, making the landing vehicle vulnerable to boulders/hills. This is acceptable for today's vehicles, which use parachutes or skycranes. However, these methods are not applicable to rockets. In this project, an autonomous precision rocket landing algorithm was developed. A safe/smooth landing spot identifying convolutional neural network (CNN), and a model predictive control (MPC) algorithm were developed to land the rocket on a safe landing spot. As the rocket approaches the surface of the planet, the CNN periodically identifies (and updates) the coordinates of a safe landing spot, while the MPC controls the rocket's engine and thrusters to land the rocket. A Mars-like physics simulation environment was built to test the algorithm. The algorithm was tested through a series of simulations, with rockets initialized at 5000 meters altitude and 250-270 meters/second of downward velocities at random orientations. The CNN achieved over 99.9% accuracy in identifying dangerous terrain. The MPC algorithm performed safe landings on any target within 550 meters of the original trajectory. The algorithm's demonstrated precision and range indicate trajectory reorientation capabilities exceeding the 90-meter threshold required for interplanetary missions. The algorithm is feasible on a real rocket, as it requires a flight computer with a power equivalent to that of ~20 Intel Xeon chips.

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